Impact of Stratospheric Ozone Zonal Asymmetries on the Tropospheric Circulation

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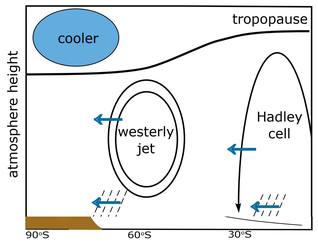
I. INTRODUCTION

- The ozone hole has played a major role in changes in the Southern Hemisphere (SH) climate [see Son *et al.*(2010), Polvani and Kushner (2002) for details].
- Waugh *et al.* (2009) shows SH climate trends are underestimated compared to full chemistry **(FC)** runs when month-mean zonal-mean **(MZM)** ozone is prescribed (as done in most CMIP models)



Objectives of this study:

to *answer following questions*:

- How robust are results of Waugh *et al.* (2009)? [They considered only single set of runs]
- If so, are observed differences in trends between FC and MZM simulations due to ozone asymmetries (as in Waugh *et al.*,2009) or due to underestimated (by interpolation) zonal mean ozone in MZM runs (as in Neely *et al.*,2014).
- Can impacts of ozone zonal asymmetry be captured using simple relaxation scheme?

II. MODEL SIMULATIONS

- 1960 to 2010 simulation of the Goddard Earth Observing System Chemistry Climate Model (GEOSCCM)[Pawson *et al.*, 2008]
- The same set-up as Waugh *et al.* (2009), *except*

- Three model configuration:

1) V4 with prescribed SSTs (older version used in Waugh et al.2009)
2) V5 with prescribed SSTs (new version)
3) V5 with coupled ocean

- Simulations with identical greenhouse gas (GHG),ODSs but different ozone fields in the radiation scheme:

ozone / Confi-guration	(i) Full chemistry [FC]	(ii) Monthly-mean Zonal Mean [MZM] ozone	(iii) Daily-mean Zonal Mean [DZM] Ozone	(iv) 3-day relaxation ozone [3-Day]
	3D Interactive stratospheric chemistry	Prescribed monthly mean zonal mean ozone from (i)	Prescribed daily mean zonal mean ozone from (i)	O_3 is relaxed to the ZM O3 on a 3 day time scale
V4	x1	x1	0	0
V5	x4	x4	x1	x3
V5-Ocean	x4	x4	0	0

REFERENCES

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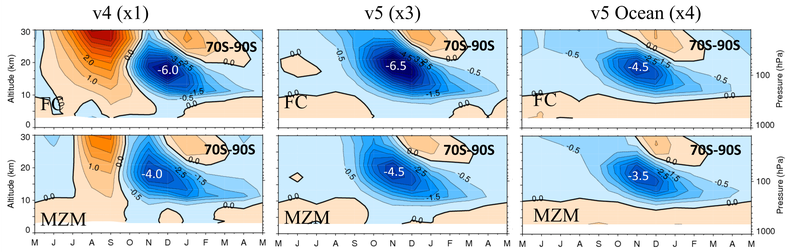
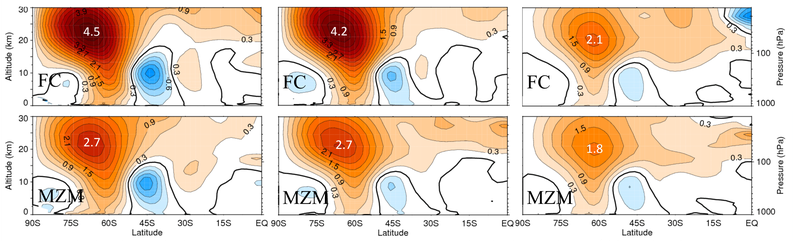
- ✓ Polvani, L. M., and P. J. Kushner (2002), Tropospheric response to stratospheric perturbations in a relatively simple general circulation model, Geophys. Res. Lett., 29(7), 1114, doi:10.1029/2001GL014284.
- ✓ Son, S.W., *et al.* (2010), Impact of stratospheric ozone on Southern Hemisphere circulation change: A multimodel assessment, J. Geophys. Res., 115, D00M07, doi:10.1029/2010JD014271.
- ✓ Neely *et al.*, Biases in southern hemisphere climate trends induced by coarsely specifying the temporal resolution of stratospheric ozone, Geophys. Res. Lett., 41, doi:10.1002/2014GL061627.
- ✓ Pawson, *et al.* (2008), Goddard Earth Observing System chemistry-climate model simulations of stratospheric ozone-temperature coupling between 1950 and 2005, J. Geophys. Res., 113, D12103, doi: 10.1029/2007JD009511.

III. RESULTS

1. 1979-2004 trends in zonal mean T and zonal-mean zonal U



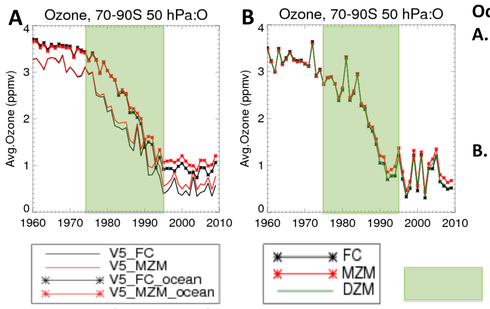
Pressure-time variation of the SH polar cap average temperature trend [K/decade] from v4, v5-prescribed SSTs and v5-coupled ocean simulations with FC (top row) and MZM ozone (bottom row).



Pressure-latitude variation in the avg. DJF zonal-mean zonal wind trend [ms^{-1}/decade] from v4, v5-prescribed SSTs and v5-coupled ocean simulations with FC (top row) and MZM ozone (bottom row).

Trend analysis shows: (1) results of Waugh *et al.* (2009) are confirmed. Weaker U and T trends in MZM than in FC runs for all models; (2) Smaller trends in coupled ocean runs compared to prescribed SST runs, but larger variability among ensembles.

3. Are differences in simulated trends due to underestimated ozone depletion in MZM simulations?



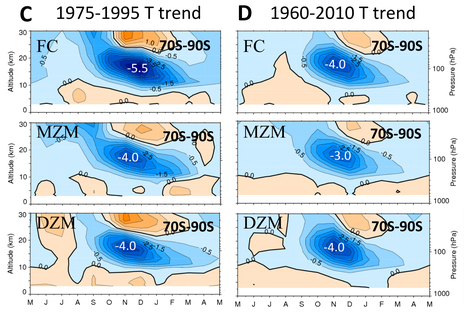
October 50hPa SH O_3 time series:

A. **Polar ozone in FC < MZM !** Due interpolation between monthly-mean values, and largest in Antarctic Sept-Dec during rapid changes.

B. **Difference between FC and DZM ozone disappears** when daily-mean values (instead of monthly- mean) are interpolated [in agreement with Neely *et al*, 2014]

Almost linear trend in stratospheric ozone between 1975 and 1995

Pressure-time variation of the SH polar cap average temperature trend [K/decade] from prescribed SSTs runs with FC (top), MZM (middle) and DZM (bottom) ozone.

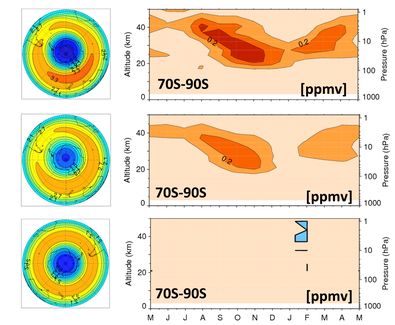


C. **1975-1995 Trends in polar temperature:**
FC > Monthly ZM ≈ Daily ZM
Results independent of interpolation method

D. **1960-2010 Trend in polar temperature:**
FC ≈ Daily ZM > Monthly ZM
[in agreement with Neely *et al.*, 2014]

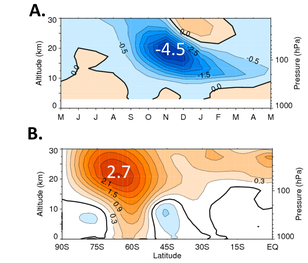
3. Are differences in simulated trends due to ozone asymmetry?

1979-2004: 50 hPa O_3 (x3) — **Standard deviation of O_3 about its zonal mean**



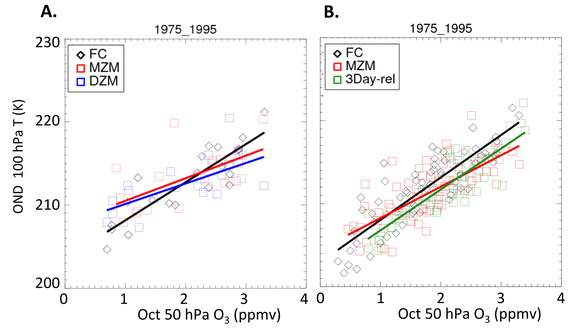
Ozone asymmetry: FC > 3-day > ZM =0 (no asymmetry)
Polar ozone: 3-day simulations further underestimate ozone depletion [ozone hole in FC > MZM>3-Day]

T and U trends In 3-Day relaxation runs (x3)



1979-2004 trends in stratospheric temperature (**A**) and DJF zonal-mean zonal wind (**B**) in 3-Day relax. are the same as in MZM ozone runs, but weaker than in FC simulations

Temperature-Ozone Relationships



Scatter plots of 100 hPa T (70S-90S) vrs 50 hPa O3 (70S-90S) indicate zonal asymmetries may be important. In particular, T-O3 relationship for MZM and DZM runs differs from FC runs, but T-O3 relationship for 3-day is similar to FC runs.

A. T-O3 relationship for a single set of V5 runs with FC (black), MZM (red) and DZM runs (blue).
B. Same as in **A** except for a set of runs (x3) with FC (black), MZM (red), and 3-Day relaxation (green) runs
- Symbols correspond to each year between 1975-1995, time interval with linear trend

IV. CONCLUSIONS

- ➢ Trends in T and U are underestimated when monthly-mean zonal mean ozone is prescribed, in agreement with results of Waugh *et al.* (2009)
- ➢ Simulations in which stratospheric ozone is prescribed at daily resolution removes bias in ZM polar ozone and DZM run produces the same T trends as in FC simulation during longer time interval which includes pre-ozone hole years (in agreement with Neely *et al.* (2014)). However, ozone asymmetries may still influence temperature trends during time of maximum ozone depletion.
- ➢ 3-Day (with zonal asymmetry but higher polar ozone) and MZM (with no asymmetry but lower than in 3-Day polar ozone) runs produce similar trends in T and U, which leads to suggestion that both, zonal mean ozone and zonal asymmetry, are important for accurate representation of these trends
- ➢ Using a relaxation scheme where O_3 is relaxed to the daily-mean zonal mean ozone on a 3 day time scale rather than prescribing zonal-mean ozone may be a computationally cheap way to capture these asymmetries and improve climatic trends

ACKNOWLEDGEMENTS

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